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Chondrule shapes as indicators of shock deformation in reduced vs. oxidized CV chondrites

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CV3 chondrites are classified into oxidized and reduced subgroups based mostly on the speciation of Fe into silicates and oxides (oxidized, CV3ox) or Fe-Ni metal (reduced, CV3red)[1,2]. Both oxidized and reduced subgroups are type 3, indicating low metamorphic grade; however, the CV3ox chondrite Allende has undergone metamorphism at higher temperatures and has experienced a greater degree of recrystallization than the CV3red chondrites Leoville and Efremovka [3]. It has been proposed that the lower extent of recrystallization in Leoville and Efremovka is due to an early impact event that deformed the CV3 parent body, causing lower porosities [4] and expelling ice from the part of the parent body where Leoville and Efremovka came from [5].

To identify evidence of deformation in the CV3 chondrites, we determined modal abundances of object types (chondrules, matrix, CAIs, etc.) and shapes of chondrules in three thin sections of CV3red chondrites (two of Efremovka and one of Leoville) and in two thin sections of CV3ox chondrites (both of Allende). Mosaics of the thin sections were prepared using the following types of images: plane polarized light and reflected light from petrographic microscope; back-scattered electron (BSE) and elemental (Na, Mg, Al, Si, P, S, K, Ca, Ti, Fe among others) maps collected by EPMA (JEOL JXA-8900 at Waseda University). Grids were overlain on the mosaic images and object types were identified at each grid node; between 1200 and 1700 points were counted on each thin section. Lengths and widths of chondrules were determined for each thin section. Ratios of (L-W)/L, where L = chondrule length and W = chondrule width, were calculated as indicators of two-dimensional chondrule shapes. As described below, distinct lengths vs. widths were identified in the CV3red chondrites, but Allende chondrules were more equant. Orientations of the chondrule lengths in the CV3red chondrites were measured and plotted in rose diagrams to evaluate similarities in chondrule orientations.

Modes show that the CV3red chondrites have lower proportions of matrix than the two CV3ox thin sections (Leoville and Efremovka matrix modes are 22-32%, compared to 34-40 mode % matrix in the two Allende thin sections) (also see [6]). Ratios of (L-W)/L tend to be near 0˜0.1 in the chondrules from Allende, indicating circular shapes in the plane of the thin section. In contrast, (L-W)/L ratios in the Leoville and Efremovka thin sections tend to be near 0.4˜0.5, indicating more elongate shapes. Chondrules in one Efremovka thin section are slightly more equant than in the other two CV3red thin sections (most [L-W]/L values 0.25˜0.40 vs. 0.35˜0.50), probably as a result of orientation of the thin section vs. fabric in Efremovka. Furthermore, rose diagrams of long axes of chondrules show that the chondrule long axes are clustered together along a common orientation in each thin section of Leoville and Efremovka.

Porous matrix would compress more easily than chondrules and CAIs, so the low abundances of matrix in the CV3red chondrites could be explained by compression during shock. Such compression of matrix is consistent with the low porosity of CV3red chondrites [4]. The elongation of chondrules along a common orientation also could result from shock deformation. Therefore, the modes, and chondrule shapes and orientations support the interpretation that CV3red chondrites were deformed by shock and that CV3ox chondrites were less affected by this impact event on the CV3 parent body [5].

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[2] Weisberg et al. (2006) Meteorites and the Early Solar System 2, Lauretta and McSween (editors) p. 19-52.
[3] Bonal et al. (2006) GCA 70, 1849-1863.
[4] Macke et al. (2011) MaPS 46, 1842-1862.
[5] MacPherson and Krot (2014) MaPS 49, 1250-1270.
[6] Ebel et al. (2009) LPSC 40, abstract 2065.

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